Nuclear Astrophysics With Tandem Accelerators

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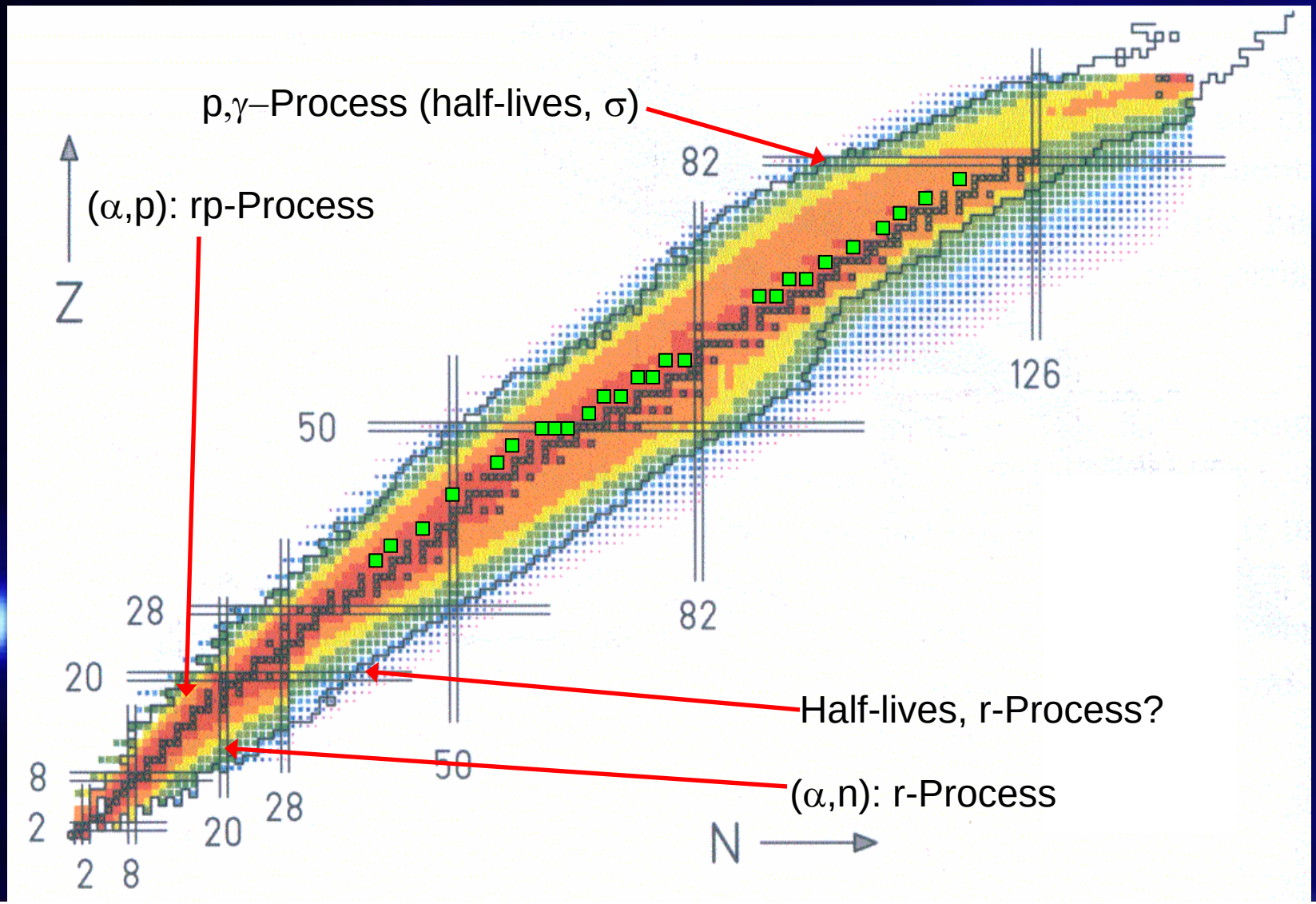
Areas of Astrophysical Interest Accessible With Stable Beams

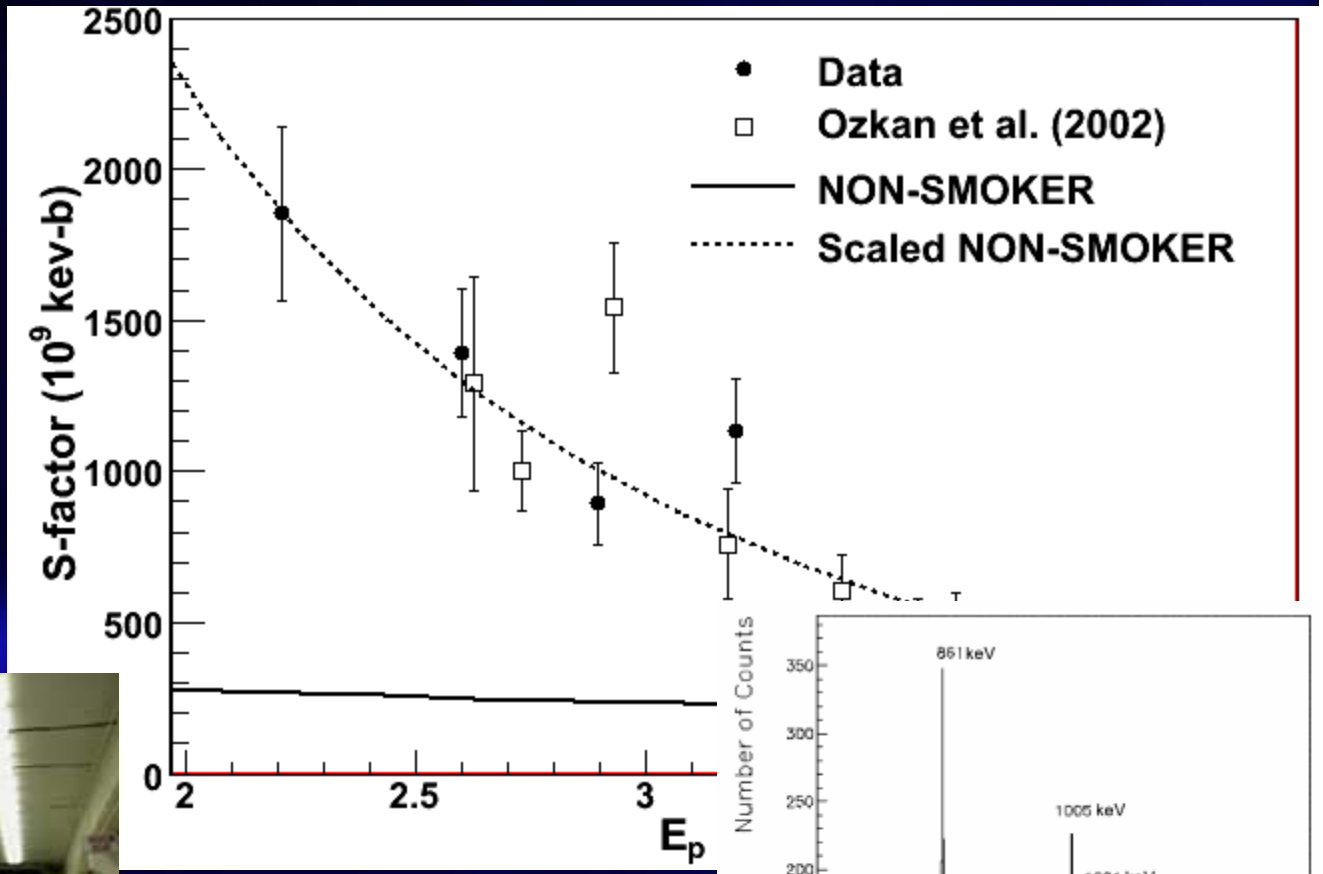


p,γ-Process Studies

p-Process nuclei
(p,γ) cross-sections
Activation technique.

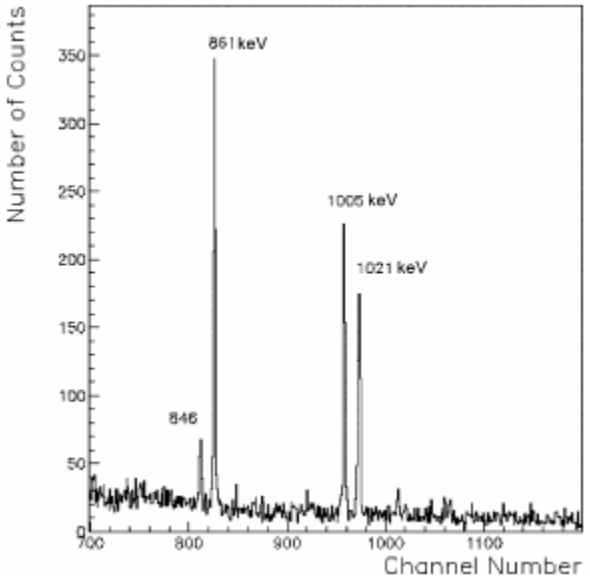
Noise and background are compensated for by relatively large σ.

Total charge < 1mC



Ozkan et al. (2002)
WMU data (submitted)

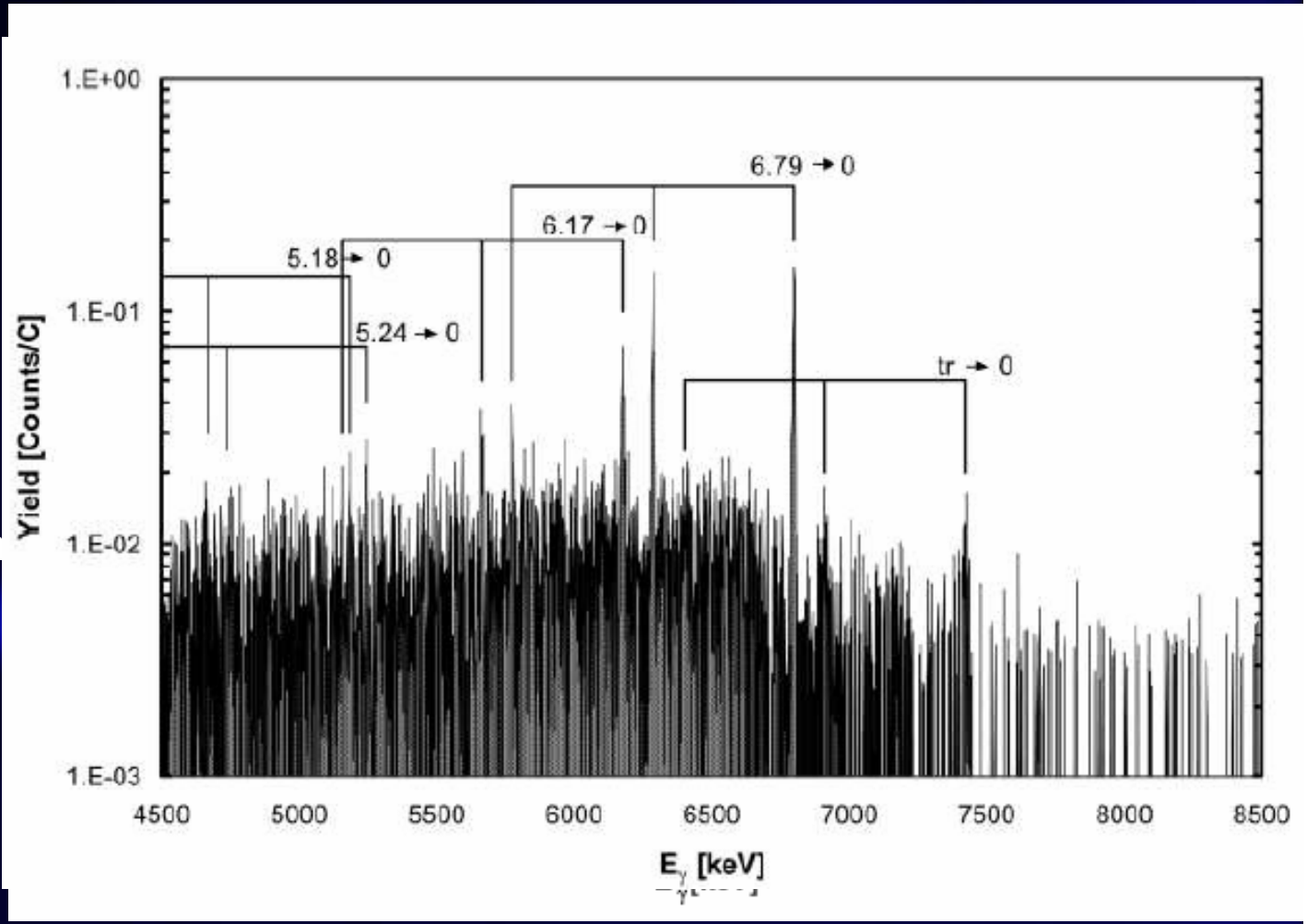
Cross sections ~ 0.1 μb possible



Very Low σ: CNO Cycle

High intensity ***useful*** for ***timely*** completion of measurement.

Extremely low background is ***essential*** for ***successful*** completion of experiment.



S-Factors measured In single keV-b

$^{14}N(p,\gamma)^{15}O$ at $119<E_{cm}<367$ keV
Imbriani et al. (2005)

Radiative Capture Cross Sections and Others

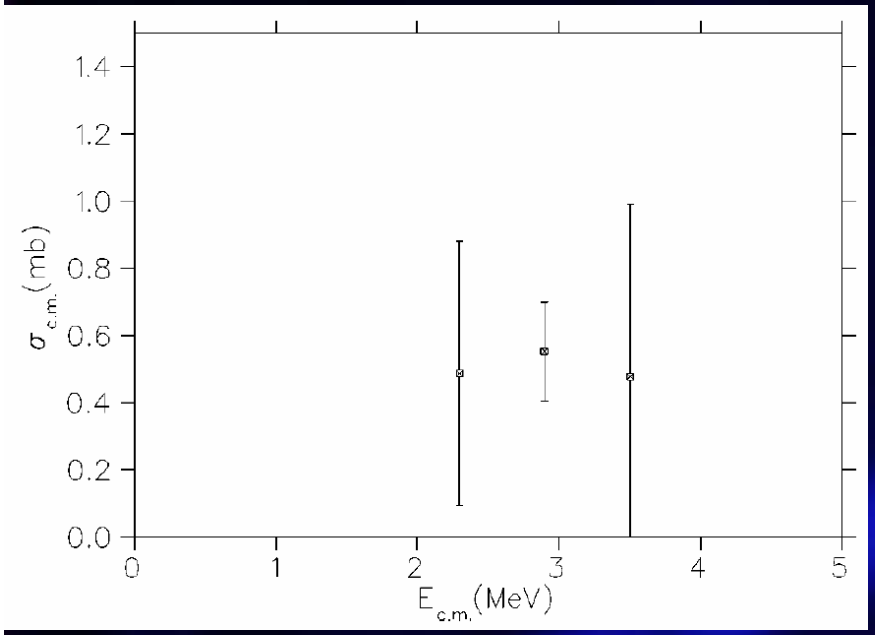
- Forward Kinematics/Direct Measurements
  - $^{3}He(\alpha,\gamma)^{7}Be$
  - $^{7}Be(p,\gamma)^{8}B$
  - $^{12}C(\alpha,\gamma)^{16}O$: Triple α
- Indirect Methods
  - $^{12}C(\alpha,\gamma)^{16}O$: Triple α
- Other Important Reactions
  - $^{22}Ne(\alpha,n)^{25}Mg$
  - $^{22}Ne(p,\gamma)^{23}Na$
- Hot CNO breakout
  - $^{15}O(\alpha,\gamma)^{19}Ne$
  - $^{18}Ne(\alpha,p)^{21}Na$
  - $^{17}O(p,\gamma)^{18}F$

Solar Burning and Neutrinos

Inverse kinematic (breakup) difficult
Due to beam-induced background.
Separation of products more difficult,
Especially with high current?

Beam-induced background!

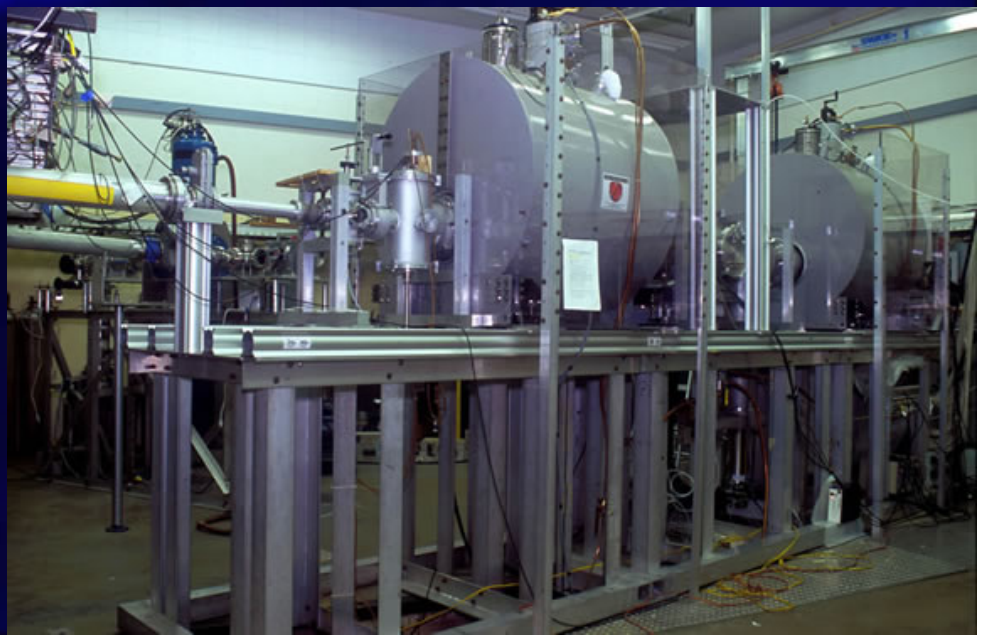
IBBN Studies: Solenoid?



^{8}Li(d,α)^{6}He cross section using silicon surface barrier detectors. Coverage can be greatly improved with thin silicon strip detectors with a possible reduction in beam-induced background with limited space.

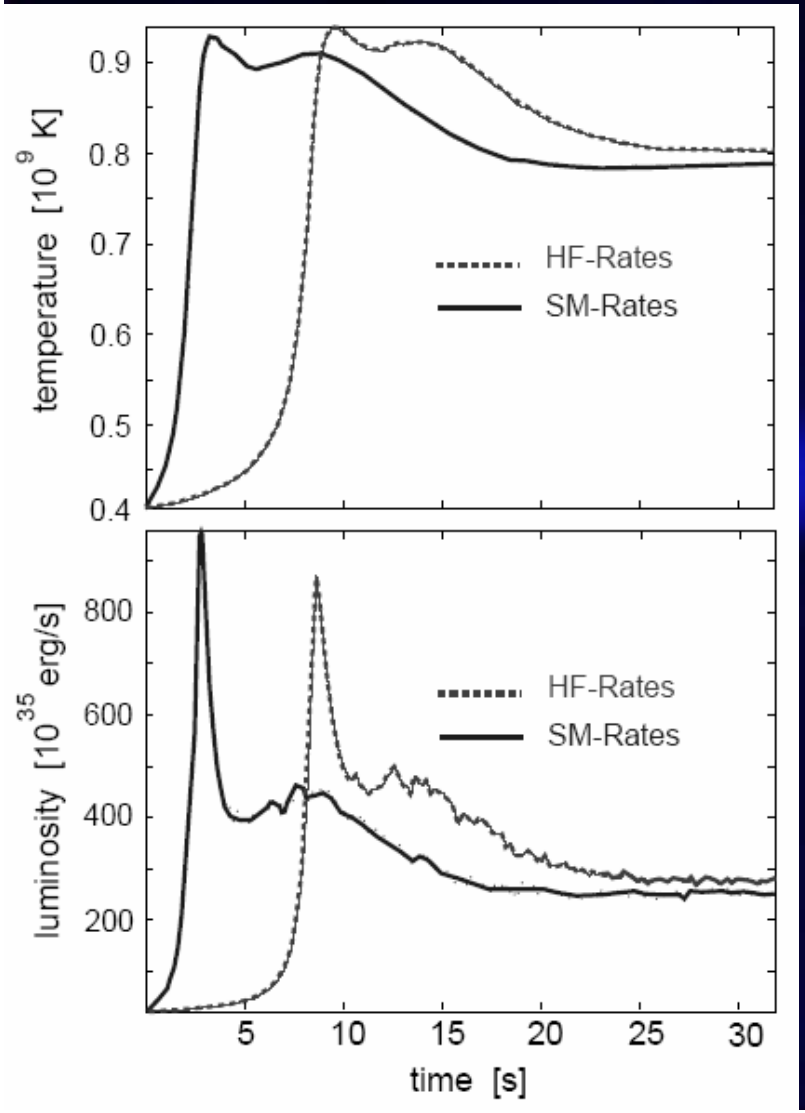
BBN reaction, controls ^{6}Li abundance in Inhomogeneous models.

Possibilities: Low energy secondary beams for astrophysically interesting reactions. E.G., ^{8}Li(d,α)^{6}He Sahin et al. (PRC 65, 38801)



Light Curve Dependence During Ignition

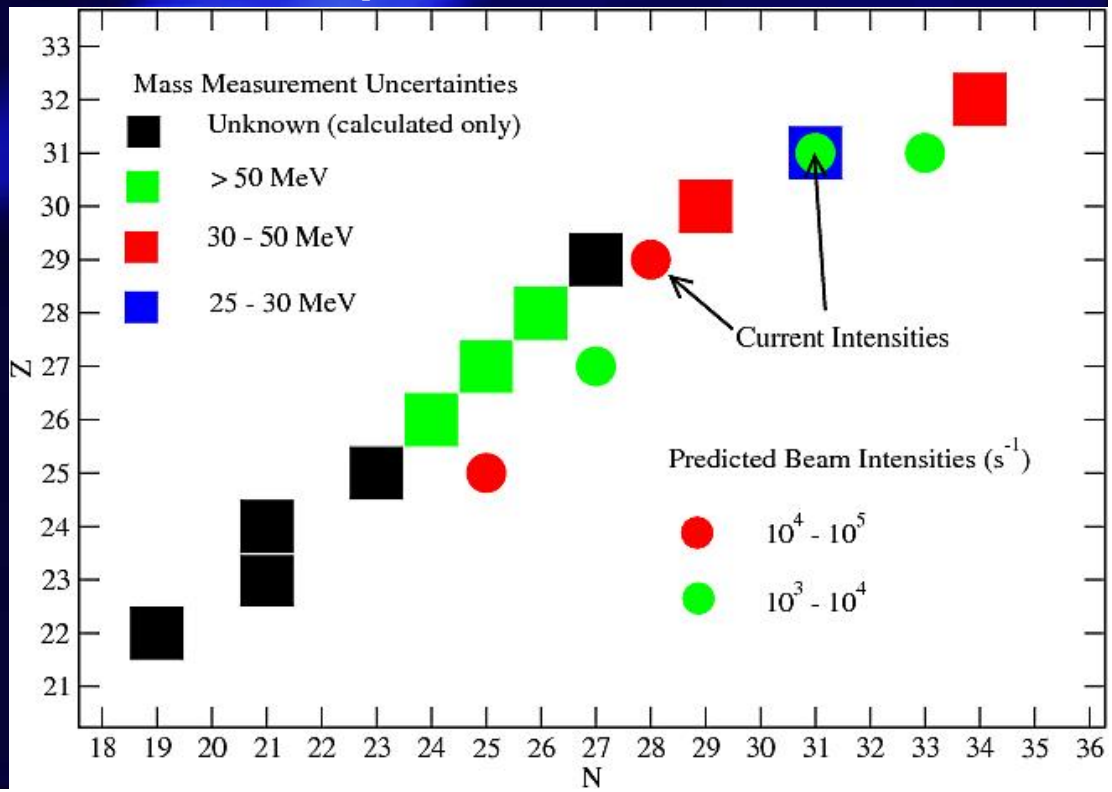
Wiescher et al. 2002



Lighter mass nuclei during ignition stages of rp-process largely ignored.

- (p,γ) reaction on $^{45\text{-}47}V$, ^{49}Mn

Knowledge of these nuclei, including level structure and S_p with σ<~50keV



Wish List

- "Minimal" requirements
  - Tandem/pelletron accelerator with a few beamlines
  - Up to ~10 MV
  - Users bring their own equipment
- Secondary additional components
  - Complement of permanent on-site detection "equipment"
  - Reduction of beam-induced background
- Enhanced capabilities
  - RI beam capabilities
    - Solenoid spectrometer?
  - Neutron TOF area

More Difficult

- Reaction and cross-section studies
  - Specific interest: (α,n) cross-sections
    - Nobody is really tackling this problem with vigor.
  - Early stages of r-Process
  - Technical issues with a direct measurement
    - Neutron detection
      - Could be quite simple
      - Maybe require liquid
    - Requires α target
    - Sufficient rates
- Still some structure relevant to the hot-CNO breakout
- Maybe some p-process studies.
  - Lifetimes of p-process nuclei
    - Done at ND-NSL and Argonne

Level Structure

- Particularly interested in high E* states (~3-5MeV) of interest to hot CNO breakout and early ignition
  - (p,γ): Good resolution, gamma detection, low reaction rates
  - Transfer: Need high N for good widths
  - Mirror nuclei studies: (d,p), Single-particle S.F., ANC's
  - (p,p'): Tougher analysis, need high N (TUDA)
- Reactions and rates
  - (α,p) reaction: Inverse kinematics

Possible Experiments

- Further mass measurements along rp-process path (or S_p)
  - E.g. ^{56}Cu, ^{61}Ga (near endpoint of rp-process path)
  - Also, A≤56 (Wiescher et al. 2002)
  - Possible with current TAMU upgrade
  - Increased sensitivity with re-accelerated beams
- In many cases, uncertainty reduction is desired
- Ignition reactions: αp-Process, Hot CNO breakout, NeNa, MgAl
  - E.g. Reaction rates in inverse kinematics
  - May require very low energies for study of the inverse reaction
  - However, levels and cluster structure studies are not precluded